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DESIGN AND IMPLEMENTATION OF TRIANGULAR PATCH ANTENNA FOR WI-FI APPLICATION

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ABSTRACT

In this paper design, optimization, fabrication and testing of a planner triangular patch antenna for Wi-Fi applications is presented at the frequency of 2.4 GHz using a FR4 substrate of thickness 1.6 mm and dielectric constant 4.4. Inset feeding has been used to feed the antenna. Patch antenna presented here was designed using microwave studio RF simulation software. This design is optimized to have better return loss at the frequency of operation. Presented antenna have been fabricated and tested. It was found that the results obtained from simulation have close agreement with the results obtained from fabricated antenna. So, the presented antenna has been found to be suitable to be used for Wi-Fi applications.

Keywords: Triangular Patch Antenna, Inset feed network, Antenna for Wi-Fi.

I. INTRODUCTION

Patch antennas are popular due to their low-profile structure. They are extremely compatible for embedded antennas in handheld wireless devices such as cellular phones, pagers etc. The telemetry and communication antennas on missiles need to be thin and conformal and are often Microstrip patch antennas.

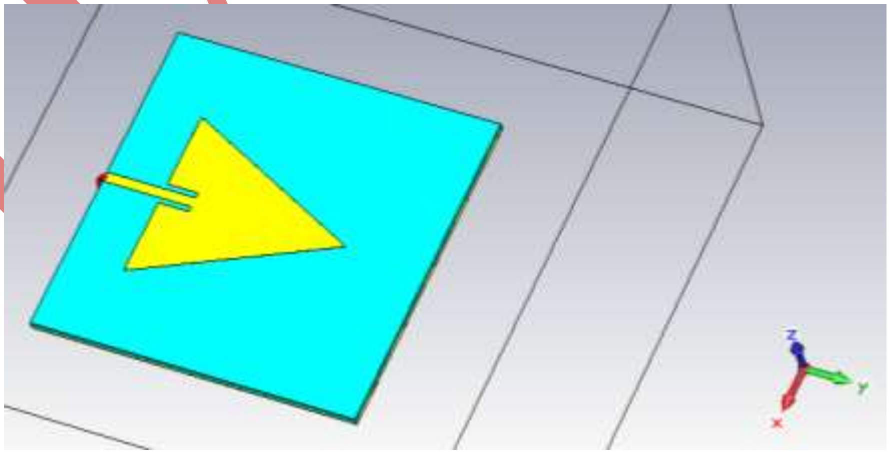


Fig.1 Shows a Typical Patch Antenna.

Another area where they have been used successfully is in Satellite communication [1]. In order to simplify analysis and performance prediction, the patch is generally square, rectangular, circular, triangular, and elliptical or some other common shape as shown in Fig. 2.

The most popular models for the analysis of Microstrip patch antennas are the transmission line model, cavity model, and full wave model (which include primarily integral equations/Moment Method) [1].

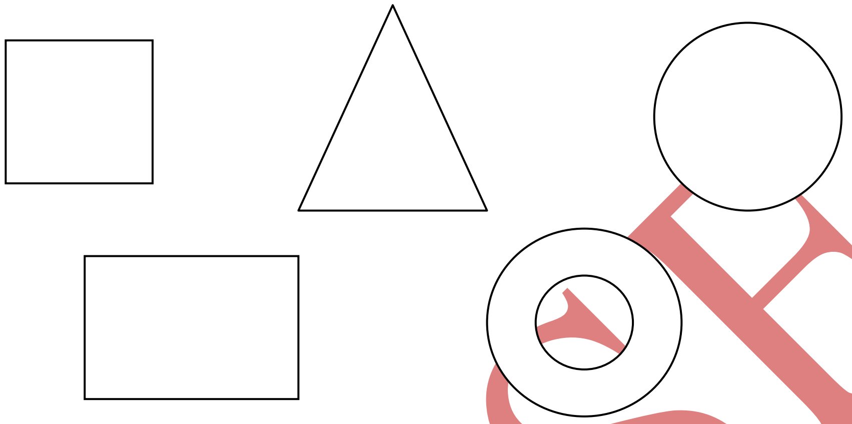


Fig.2 Different Shapes of Patch Antenna

The transmission line model is the simplest of all and it gives good physical insight but it is less accurate. Transmission Line Model, in which the microstrip antenna is viewed as a transmission line loaded at both ends, is easy to deal with and to visualize the underlying effects but is less accurate than the other two. This model usually is not used for very thin substrates.

From this model, width, length, and radiation resistance (among other antenna characteristics) can be calculated and designed based on a desired resonant frequency, dielectric material, and substrate thickness [1].

An effective dielectric constant (ε_{reff}) must be obtained in order to account for the fringing and the wave propagation in the line. The value of ε_{reff} is slightly less than ε_f because the fringing fields around the periphery of the patch are not confined in the dielectric substrate but are also spread in the air. The expression for $\varepsilon_{reff}$is given by Balanis [1] as represented here:

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{1/2}$$

Where ε_{reff}= Effective dielectric constant

ε_r = Dielectric constant of substrate

h = Height of dielectric substrate

W = Width of the patch

The fringing fields along the width can be modeled as radiating slots and electrically the patch of the microstrip antenna looks greater than its physical dimensions. The dimensions of the patch along its length have now been extended on each end by a distance ΔL, which is given empirically by Hammerstad as [2], [5]:

$$\Delta L = 0.412h\frac{(\varepsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)}$$

The effective length of the patch L_{eff} now becomes:

$$L_{eff} = L + 2\Delta L$$

For a given resonance frequency $f_0$the effective length is given by [2] as:

$$L_{eff} = \frac{c}{2 f_o \sqrt{\varepsilon_{reff}}}$$

For a triangular Microstrip patch antenna, the resonance frequency for any TM mn mode is given by [2]:

$$f_r = \frac{2c}{3a\sqrt{\varepsilon_r}}\sqrt{m^2 + mn + n^2}$$

Where,

m and n are number of modes

c = speed of light

a = side length of triangle

ε_r = Dielectric constant of substrate

The given equation does not provide a direct calculation to the patch's length, so the calculation of the patch can be made by using the effective length, a_e of the patch as in the equation below:

$$f_{10} = \frac{2c}{3a_e\sqrt{\varepsilon_r}}$$

Actual length of the patch does not vary much from this value.

a_e is effective side length of triangle and is given by:

$$a_e = a\left[\begin{array}{l} 1 + 2.199\frac{h}{a} - 12.853\frac{h}{a\sqrt{\varepsilon_r}} + 16.436\frac{h}{a\varepsilon_r} \\ + 6.182\left(\frac{h}{a}\right)^2 - 9.802\frac{1}{\sqrt{\varepsilon_r}}\left(\frac{h}{a}\right)^2 \end{array}\right]$$

It is important that impedance of the patch should match with impedance of input line. Here in this paper we have used inset feeding to feed the antenna. So, input impedance is matched to the impedance of input line by changing the feed depth. Resonant input impedance can be changed by using inset feed, recessed a distance y_0 from initial position. This technique can be used effectively to match the antenna using a microstrip line feed whose characteristic impedance is given by:

$$Z_c = \begin{cases} \frac{60}{\sqrt{e_{reff}}} ln\left[\frac{8h}{W_0} + \frac{W_0}{4h}\right] & W_0/h \leq 1 \\ \frac{120\pi}{\sqrt{e_{reff}}\left[\frac{W_0}{4h} + 1.393 + 0.667 ln\left(\frac{W_0}{h} + 1.444\right)\right]} & W_0/h > 1 \end{cases}$$

W_0 is width of microstrip line. Using modal expansion analysis input resistance for inset feed is given by [3], [5] :

$$R_{in} = \frac{1}{2G_1} cos^2\left(\frac{\pi}{L} y_0\right)$$

G_1 is conductance and is given by:

$$G_1 = \begin{cases} \frac{1}{90}\left(\frac{W}{\lambda_0}\right)^2 & W \ll \lambda_0 \\ \frac{1}{120}\left(\frac{W}{\lambda_0}\right)^2 & W \gg \lambda_0 \end{cases}$$

Y_0 is position of the patch from input position.

Inset feed insert a notch which in turn introduces a junction capacitance. This notch and capacitance influence slightly the resonance frequency. This is generally varied by 1%. Its maximum value occurs at edge where voltage is maximum and current is minimum. The minimum value occurs at the center of the patch where voltage is zero and current is maximum. As the inset feed point moves from edge towards the center of the patch the resonant input impedance decreases monotonically and reaches zero at the centre. So, input impedance changes rapidly with the position of the feed point [5].

II.DESIGN & SIMULATION OF TRIANGULAR PATCH ANTENNA

Design Parameters:

Substrate used: FR4
Permittivity of substrate ϵ_r = 4.4
Height h = 1.6 mm

Resonating frequency f_r	2.4 GHz
SL (Substrate Length)	60 mm
SW (Substrate Width)	60 mm
a (input line gap)	0.98 mm
l (Input line depth)	5.7 mm
lm Input line length	16.59 mm
Calculated Side Length of Patch	30.21mm
Calculated Dimensions for 50 ohm Inset feed line	1.835 mm

According to design parameters, the microstrip antenna was simulated on EM simulator. The return loss and radiation characteristics of microstrip patch antenna are shown in figures 3 through 10. Figure 3 shows the structure of designed antenna.

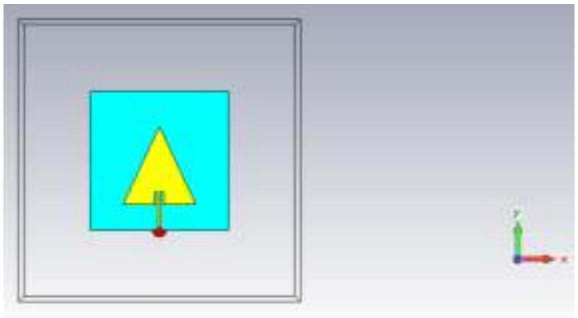


Fig.3 Layout of Triangular Patch Antenna

Figures 4 through 10 shows the results obtained in simulation of the triangular patch antenna. Figure 4 shows the initial return loss of antenna dimensions after calculations.

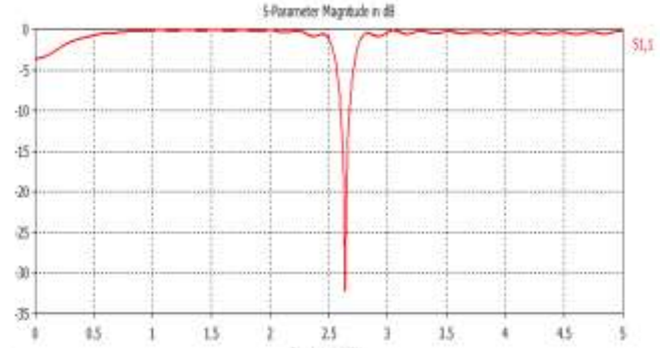


Fig.4 Initial Return loss obtained trough calculations

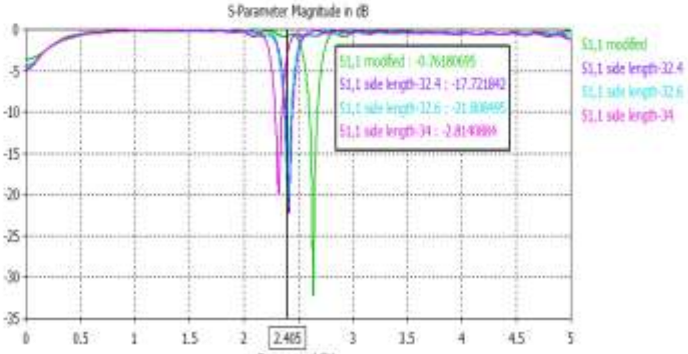


Fig.5 Initial and Modified Return loss

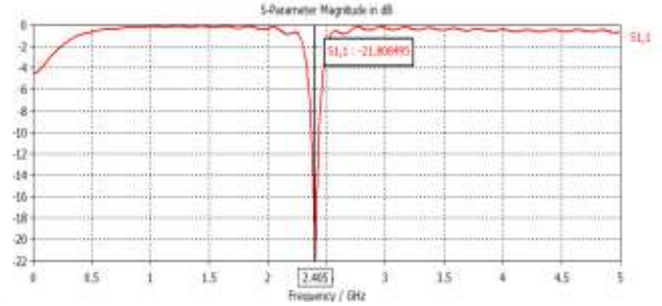
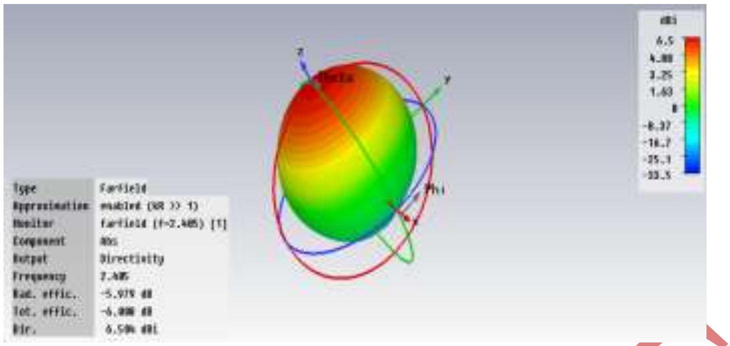
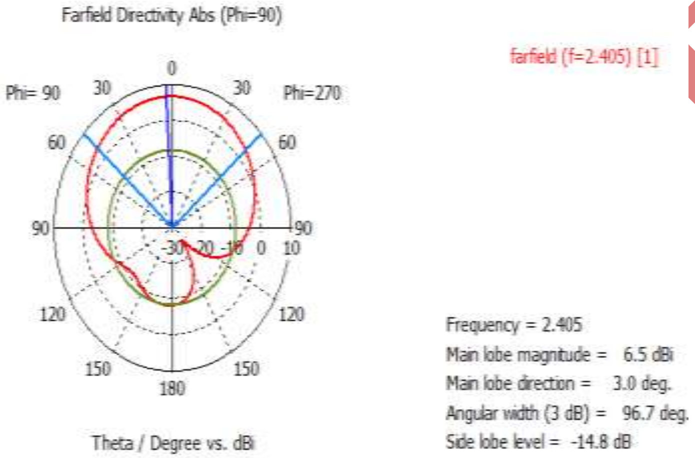


Fig.6 Optimized Return loss of triangular patch antenna



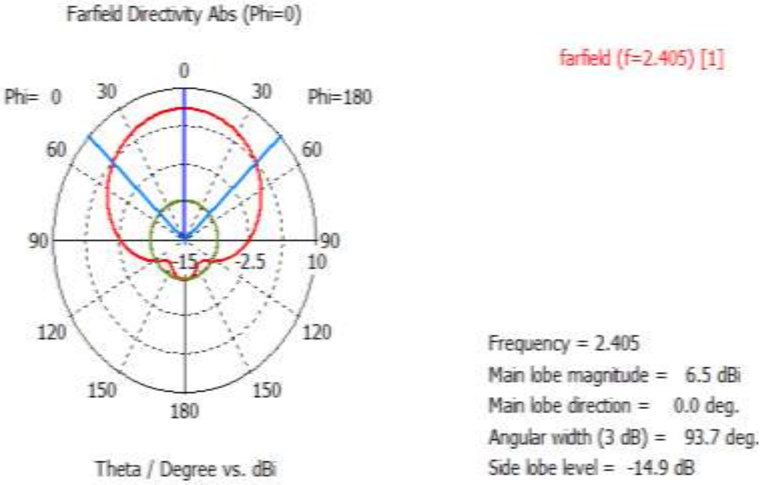
Type	Farfield
Approximation	enabled (kR >> 1)
Monitor	farfield (f=2.405) [1]
Component	Abs
Output	Directivity
Frequency	2.405
Rad. effic.	-5.979 dB
Tot. effic.	-6.008 dB
Dir.	6.506 dBi

Fig.7 3-D radiation of triangular patch antenna



Frequency = 2.405
Main lobe magnitude = 6.5 dBi
Main lobe direction = 3.0 deg.
Angular width (3 dB) = 96.7 deg.
Side lobe level = -14.8 dB

Fig.7 H-plane Polar plot of triangular patch antenna



Frequency = 2.405
Main lobe magnitude = 6.5 dBi
Main lobe direction = 0.0 deg.
Angular width (3 dB) = 93.7 deg.
Side lobe level = -14.9 dB

Fig.8 H-plane Polar plot of triangular patch antenna

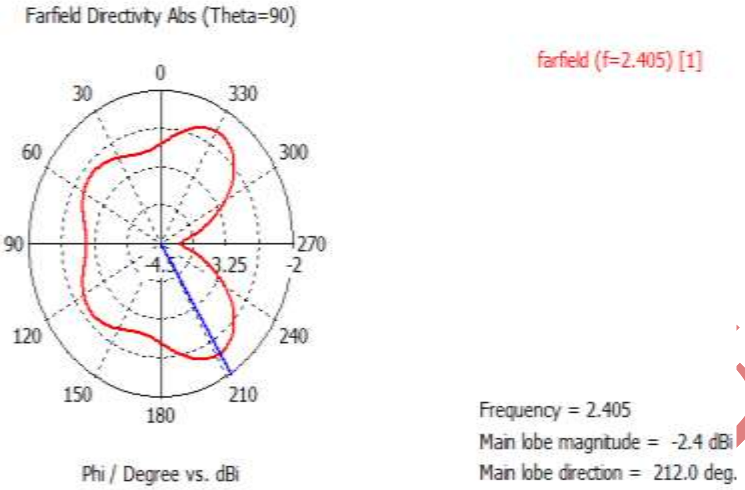


Fig.9 E-plane Polar plot of triangular patch antenna

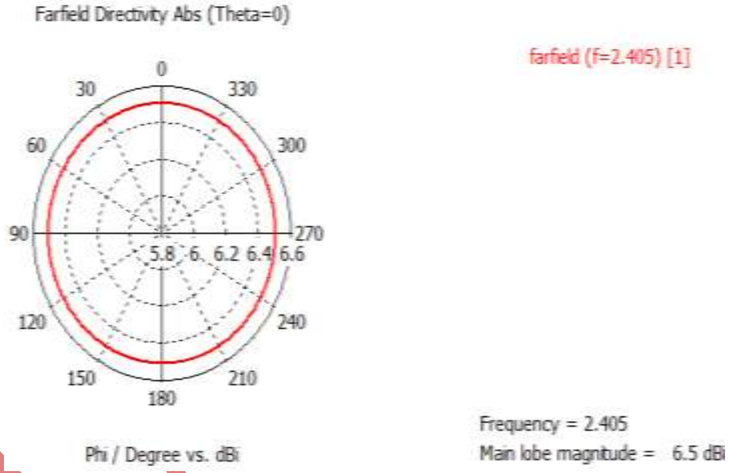


Fig.10 E-plane Polar plot of triangular patch antenna

After optimization of the parameters the patch was fabricated using microwave integrated circuit (MIC) technique.

III FABRICATION

To prepare the layout of the distributed elements obtained, Intellicad software was used. I-CAD layout has been shown in figure 11. After photolithography process the fabricated structure was obtained as shown in Fig.12. The fabricated circuit tested on vector network analyzer that is shown in Fig.13 and Fig.14.

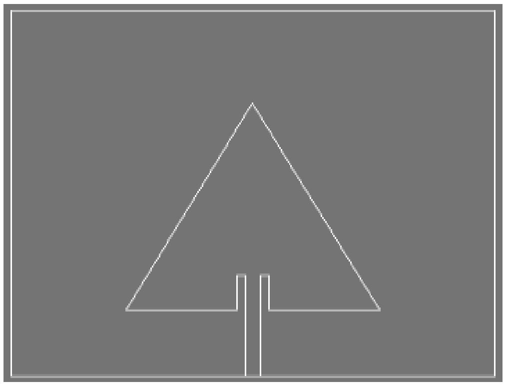


Fig.11 I-CAD Layout of Triangular Patch Antenna

Fig.12 Fabricated Triangular Patch Antenna

Fig.13 Measurement Set-up and Snap shot of VNA screen during measurement

Figure 14 clearly shows that the practical results are in close agreement with the theoretical results.

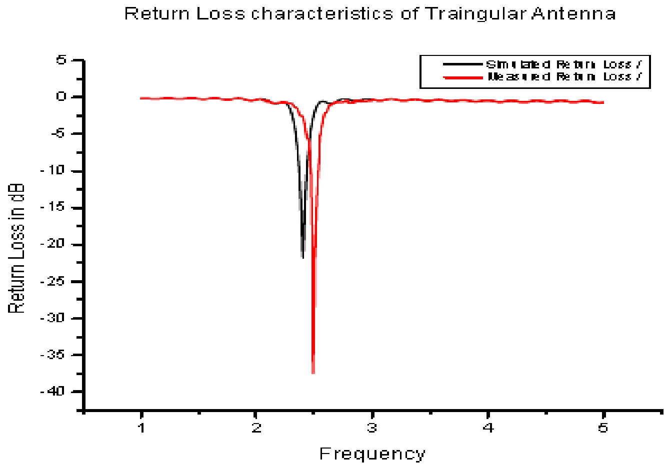


Fig.14 Comparison of measured and simulated return loss

IV RESULTS AND CONCLUSION

Following table 1 provides the comparison of result obtained through simulation and then fabrication.

TABLE 1

COMPARISON OF RESULTS OBTAINED

S.No	Parameter	Simulation Results	V.N.A Results
1	Resonating Frequency	2.40	2.49
2	Return Loss	-26 dB	-37.4 dB
3	10 dB B.W.	67 MHz	65 MHz

The proposed design of triangular patch antenna has close agreement between simulated and measured results. The designed antenna can be used for Wi-Fi application. It can be used to form array also.

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